The Role of Epistemic Cognition in Secondary Computer Science Teaching

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Given the limited pre-service opportunities available for aspiring computer science (CS) teachers, alternative pathways into CS teaching exist for in-service educators through various teaching endorsements and accreditation (Lang, Galanos, Goode, Seehorn, & Trees, 2013). These manifold pathways draw teachers of assorted disciplinary backgrounds and experiences into CS classrooms. Depending on their entry into CS teaching, educators will likely vary in the ideas they hold about teaching and learning in general and about CS specifically. Since these individual differences influence teachers' instructional strategies (Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008), attending to their epistemic beliefs can further our understanding of how best to support experienced educators who are transitioning into CS teaching.

Theoretical Framework

Epistemic cognition concerns ideas people hold about the nature and acquisition of knowledge. Chinn, Buckland, and Samarapungavan (2011) described epistemic cognition as relating to (a) inquiry goals and the worth associated with achieving goals (i.e., epistemic aims and values); (b) how knowledge is structured; (c) the origins of knowledge, the reasons for one's beliefs, and the attitudes taken towards ideas; (d) dispositions that support or hinder epistemic aims; and (e) processes for achieving epistemic aims. Teachers' epistemic cognitions are reflected in their instructional decisions (e.g., minimizing required material they believe does not support disciplinary thinking) and in the ways they engage with content in class (e.g., responding to students' alternative methods), which may convey ideas to students about the preferred epistemic cognitions to assume for a given discipline (Buehl & Fives, 2016). Scholars studying epistemic cognition have categorized teaching viewpoints on a spectrum ranging from more teacher-focused, didactic beliefs that view teachers as conveyors of knowledge and students as receptacles of that knowledge to more student-focused, constructivist beliefs that view students as constructors of their knowledge and teachers as facilitators of this process (e.g., Brockmeyer, 1998; Hashweh, 1996; Luft & Roehrig, 2007; Peterson, Fennema, Carpenter, & Loef, 1989; Simmons et al., 1999). Researchers have found that teachers espousing constructivist views of teaching and learning notice students' conceptions more and use more varied instructional strategies (Hashweh, 1996; Peterson et al., 1989).

Epistemic cognitions also vary across disciplines. For example, while scientists aim to make the most accurate claims possible by building theoretical models of the natural world based on data, those interpreting literary texts aim to explore the human experience by attending to the language content and form of texts which are open to multiple interpretations (Lee, Goldman, Levine, & Magliano, 2016). Within CS, three paradigms dominate the discipline that differ in their aims and processes (Eden, 2007; Tedre & Sutinen, 2008). The rationalist approach views CS as a branch of mathematics that aims for coherent theoretical structures and systems and seeks a priori knowledge of program correctness through deductive reasoning. The technocratic approach views CS as a branch of engineering that aims for useful, efficient, and reliable systems, and seeks a posterior knowledge of program reliability through empirical methods. The scientific approach views CS as a natural science that aims to investigate and explain phenomena, and seeks to explain, model, and predict the behavior of programs using both deductive and empirical methods. Teachers entering CS for the first time may confront epistemologies that differ from their known experiences and require adopting new ways of teaching.

Epistemic cognition of CS educators is an understudied topic. Some prior work has identified the ideas teachers possess about the discipline (e.g., one's problem solving approach matters more than finding the right solution) (Carbone, Mannila, & Fitzgerald, 2007; Lewis, Jackson, & Waite, 2010). Another study conducted by Kordaki (2013) revealed two prominent belief types of CS educators in Greece: empowering beliefs more aligned with constructivist views and constraining beliefs more aligned with behaviorist views. The objective of this paper is to further our understanding of epistemic cognition in CS by exploring the beliefs of experienced secondary teachers new to teaching CS.

Study Context and Methods

This study is a component of a larger project to study in-situ training for secondary CS teachers. The project focuses on a multiyear professional learning (PL) program that uses a co-teaching model involving volunteers from the tech industry. At the time of this study, two courses were offered through the program: the semester-long *Intro* course and the year-long *AP Computer Science A* (AP) course. During the 2015-2016 school year, I conducted a case study with four teachers in the U.S. who were participating in the PL program. Ms. Jones and Mr. Miller taught the Intro course. Ms. King and Ms. Robinson taught the AP course. All four teachers also taught mathematics courses. Teachers were visited six times in their CS courses and once in their mathematics course. At each visit, I gathered observational, interview, and questionnaire data. At the end of the school year, teachers completed a questionnaire about their epistemic cognitions and CS teaching knowledge. In this paper, I focus on the epistemic cognition questionnaire to explore participants' ideas about processes for achieving epistemic aims in CS.

Teachers answered four open-ended items drawn from Luft and Roehrig's Teacher Beliefs Interview (2007): how do you maximize student learning in your classroom?; how do your students learn CS best?; how do you describe your role as a teacher?; and in the school setting, how do you decide what to teach and what not to teach? Luft and Roehrig identified five categories of beliefs ranging from more teacher-centered beliefs to more student-focused beliefs (i.e., traditional, instructive, transitional, interactive, and responsive) that were used to code participants' responses (see Table A1). Based on Kordaki's (2013) finding that CS teachers often held multiple yet conflicting beliefs, participant responses could receive more than one code if multiple ideas were expressed. Interview data supplemented the questionnaire responses. Before presenting the results, it is worth noting that within the CS education community today, student-centered beliefs are encouraged and reflected in both teacher training materials (e.g., use of active learning; Hazzan, Lapidot, & Ragonis, 2015) and course frameworks (e.g., inquiry practices in the ECS curriculum; Margolis, Goode, Chapman, & Ryoo, 2014).

Research Findings

Beliefs about Teaching. All teachers expressed contrasting ideas when commenting on beliefs about teaching (see Figure A1). When asked how they make decisions about what to teach, all respondents expressed traditional beliefs saying they used their curriculum as a guidepost. As Ms. King wrote, "I stick pretty closely to the AP curriculum, since that's the measuring stick." Several teachers had opportunities to teach material beyond their curriculum, and here they expressed different ideas about deciding what to teach. Ms. Jones and her volunteers created an introduction to Java to follow their Intro course. Concerning the development of this introduction, she remarked that "decisions were mostly based on the volunteer's wisdom and what students would need to be prepared for taking AP CS in the future", an instructive belief. Ms. King and Ms. Robinson expressed interactive beliefs when discussing how they structured the weeks after the AP exam; both gave students time to explore computing topics of their own interest.

In contrast, when asked to describe their roles as teachers, participants offered more student-centered beliefs. Ms. Jones saw herself as responsible for providing a safe and structured learning environment, a transitional belief. Ms. Robinson saw herself as a collaborator who helps and is helped by her students, an interactive belief. She said, "students and I worked together to help each other. There are a handful of students who are very proficient in CS, so I tap into their knowledge for assistance to help the rest of the class". Lastly, both Ms. King and Mr. Miller saw themselves as guides to facilitate students' learning, a responsive belief. As Mr. Miller commented, "I describe my role as a resource guide. Students really only learn and retain what they learn by doing, by working to complete a task. I believe my role is to be a facilitator of this productive struggle."

Curriculum goals appeared to create tension between participants' beliefs about teaching and their instructional practices. This friction was notable in Ms. King who commented about her struggles to balance her preferred style of teaching with the AP curriculum:

> As I become more familiar with the AP, I am thinking more about [how the AP asks questions], and less about the way I learned to code, which is, "I have to do something, how do I do it, oh this works". So that was how I taught the first couple years…but [that doesn't] give you the best written and most efficient code…What I don't like about teaching the AP is that we stop having fun while we review. What I do like about the AP is that it structures the curriculum, emphasizes what I should be emphasizing…If I knew a little more, I'd be pass the AP, and I'd be wanting to teach it my own way.

Beliefs about Learning. Teachers expressed beliefs about how students learn CS that were mostly transitional and interactive (see Figure A2). When asked how students learn CS best, all teachers said “by doing” or “by practice”, a transitional belief. However, for most teachers, this was not sufficient. For example, Mr. Miller distinguished programming as a part of CS and offered a comment reflecting more interactive beliefs:

> My students learn "Computer Programming" best by trial and error performance. They must be able to write code, recognize errors and then debug them, making corrections to their code. "Computer Science", however, incorporates much more than programming. The best way to learn CS is to research aspects of interest to students and to recognize how what they learn can apply to their daily life. To help students recognize such useful applications, a class "discussion" is often helpful.

Ms. Robinson also expressed an interactive belief. She thought students also learned CS by simulating programs with their peers and giving short presentations about topics they researched. In contrast, Ms. Jones expressed a more traditional belief saying that students “need some guidance and direct teaching. After that, working on projects in lab time and generating solutions on their own seems to work.”

When asked how they maximize student learning, teachers expressed a range of beliefs from traditional viewpoints to interactive viewpoints. Ms. King, Mr. Miller, and Ms. Jones maximized learning by providing student opportunities to interact with and learn from each other, an interactive belief. For example, Mr. Miller said, “to maximize student learning, I encourage students to work together with others in completing a task…I believe that working with peers allows students to understand concepts well enough to explain them to their peers.” Mr. Miller, Ms. Jones, and Ms. Robinson also maximized student learning by creating classroom environments that were safe or involved multiple activities, transitional beliefs. Both Ms. King and Ms. Jones also expressed instructive ideas related to monitoring students (e.g., using short deadlines, prodding off-task students). Ms. Jones also discussed traditional ideas related to creating a structured environment for learning by using a daily routine and providing prepared lessons.

Beliefs across Disciplines. In addition to responses on the beliefs questionnaire, teachers offered anecdotal evidence comparing their epistemological beliefs in mathematics and CS. During non-CS class visits with three of the teachers, participants commented on similarities and differences of teaching the two disciplines. Ms. King taught support mathematics classes in addition to the AP CS course. Her teaching in the AP CS course seemed more aligned with her transitional and student-centered beliefs than her mathematics teaching. She preferred to "demonstrate how to do something, and then they work independently while I come around and help them", but found this was easier to accomplish in her CS classes because students chose to enroll in the class. She believed students in her mathematics course lacked motivation which led her to use more direct instruction. Both Ms. Jones and Ms. Robinson discussed how the nature of CS and mathematics at the high school level differed, creating a need for different styles of teaching. For example, Ms. Jones commented, "I would say in computer science, it is probably more big picture problem solving, whereas in math, it is more procedural and less creative...The strategies are different because in computer class it is mostly lab time, so it is a lot of one-on-one [time] or they have to talk to their neighbor. It is just learning through doing. Whereas like in math, a lot of it is just teacher guided practice." These comments suggest that epistemological beliefs vary across disciplines and that the nature of disciplines and students' abilities and motivation strongly influence instructional choices.

Conclusions

Participant comments related to beliefs about teaching reflected different belief categories. These differences seem to reflect concomitant ideas stemming from teachers' own beliefs and external factors to which teachers are accountable. Teachers sometimes bent their practices to accommodate external factors and other times they tried to weave their own beliefs into classroom activities, what Fang (1996) calls the inconsistency thesis. Responses related to beliefs about student learning showed that participants believed students learn CS best with a variety of activities that include some form of peer exchange and the space to pursue topics of interest. These student-centered beliefs were reflected in the setup of the teachers' classrooms and the structure of their instructional activities. For example, Ms. King implemented a flipped classroom where students watched online lectures at home and spent most class time working on projects collaboratively. Ms. Jones frequently incorporated peer grading into her labs. While the use of various activities aligned with teachers' beliefs of student learning, it did present teachers with a management challenge. Using various activities allowed students to move at their own pace, which also meant students needed a lot of individualized support. Lastly, anecdotal evidence gathered from Ms. King, Ms. Jones, and Ms. Robinson suggests that different disciplines may activate different epistemic ideas in some teachers.

This study was an initial attempt to understand the epistemic beliefs of four teachers transitioning into CS. Given the limited amount of prior research on this topic, I assumed an exploratory focus for this study. Obviously, such an approach limits the generalizability of this work and raises questions about epistemic beliefs of teachers working in other contexts. Here, I offer suggestions for future work to further enhance our understanding of epistemic beliefs in educators new to teaching CS. Participants reflected on their beliefs about teaching and learning

CS once at the end of the school year. Future studies might investigate whether and how epistemic beliefs of transitioning CS teachers change over time. For example, how long does it take to see a shift in epistemic beliefs? Or, how are shifts in epistemic beliefs reflected in teaching practices? Another area of research to explore is epistemic beliefs across disciplines. For example, current CS courses promote a vision of education aligned with reform teaching. Does this encourage teachers to bring reform practices to their other courses? Also, there seems to be a popular belief that mathematics and CS are closely related disciplines so it is easier for a mathematics teacher to learn CS content than a teacher trained in another subject. But how do transitioning teachers from other, supposedly less similar, subjects adapt to CS epistemologies?

Given the demand for more CS learning opportunities in American schools, educational agencies are turning to in-service teachers to increase their CS teaching force. The results of this study suggest that epistemic beliefs play a role in how these teachers transition into their new courses and the teaching practices they use in their classrooms. More research focused on epistemic beliefs could inform the design of PL opportunities that are differentiated for teachers of varying disciplinary backgrounds and influence how we measure, and improve, the impact of PL programs targeting teachers new to CS.

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Appendix

Table 1

Teaching Belief Categories (Wong & Luft, 2015, p. 627)

Category	Orientation	Description and *Example*
Traditional	Teacher-centered	Focus is on teacher providing information and resources in a structured manner and environment *I decide what students need to know when planning my lessons*
Instructive	Teacher-centered	Teacher decides experiences and reacts based on subjective evaluation of student actions and performance *I will look at student responses*
Transitional	Both teacher-centered and student-centered	Emphasis on teacher–student relationship that includes subjective and affective components that does not necessarily focus on teaching or learning of [computer] science *By using different types of activities for different learning styles*
Interactive[1]	Student-centered	Centers on opportunities and value of collaboration between students and teacher, as well as between students as peers. Focus is on development of [computer] science learning and content knowledge *Student have opportunities to engage in discussion with the teacher and peers*
Responsive[2]	Student-centered	Focus on individualized and student-centered methods of learning that considers student responses, interests, and abilities. Promotes a collaborative environment in which students apply skills and knowledge to novel situations *Students learn in different ways and have different interests. I consider the various ways to support content learning so that students can utilize existing skills and develop new skills*

[1,2]Note: Wong and Luft originally used the terms *responsive*[1] (instead of interactive) and *reform-based*[2] (instead of responsive) in their categorization scheme, which differ from the usage of these terms in other teacher learning literature. The key distinction is that one category (i.e., responsive, or what Wong and Luft term reform-based) goes beyond a simple focus on ensuring students share their ideas to a focus on pursuing those ideas. To distinguish the nuances of these terms, I offer the categories of *interactive* to describe beliefs centered on providing opportunities of students to exchange ideas and *responsive* to describe beliefs centered on taking up students' ideas in instruction.

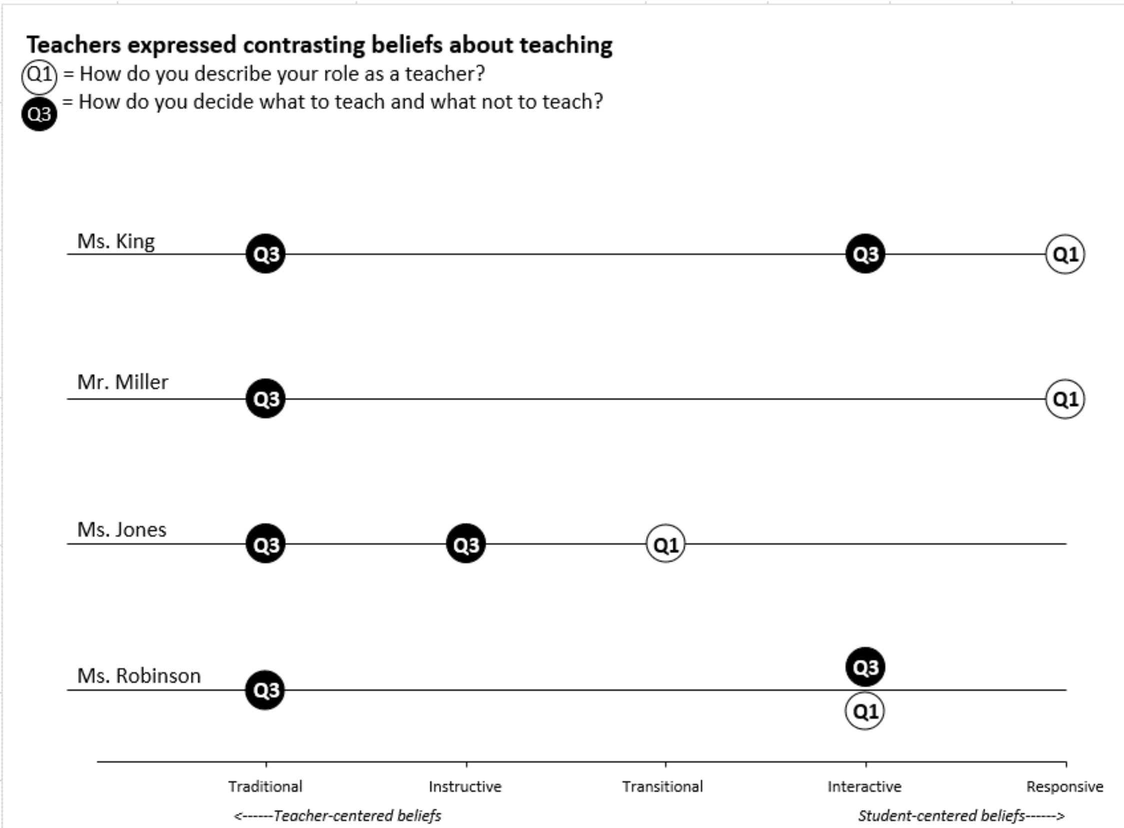

Figure 1. Participants' beliefs about teaching categorized using modified version of Luft and Roehrig's (2007) five-category belief coding scheme. Each response could receive multiple belief codes.

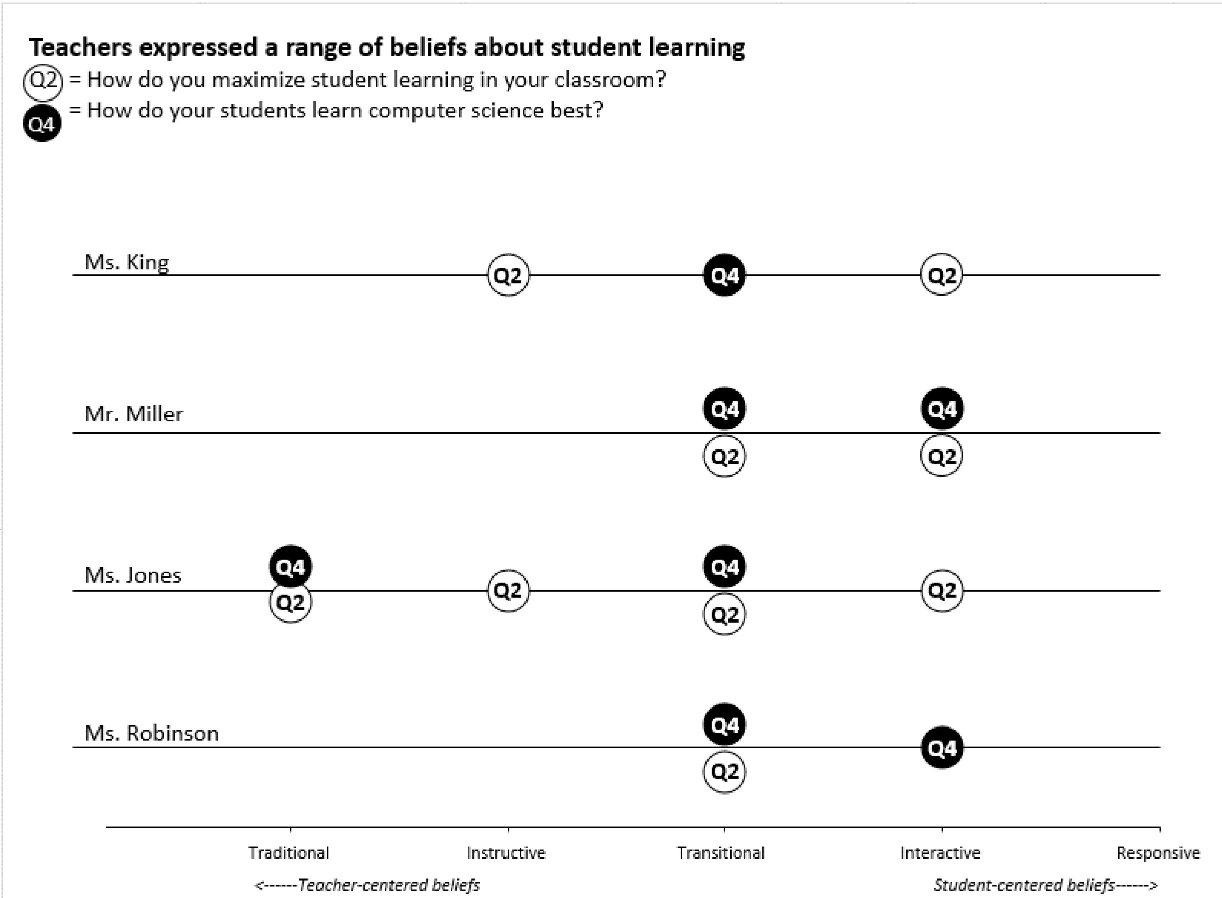

Figure 2. Participants' beliefs about student learning categorized using a modified version of Luft and Roehrig's (2007) five-category belief coding scheme. Each response could receive multiple belief codes.